Potential Impacts of a Stump Lake Spill On Downstream Water Users

Addendum to the Devils Lake, North Dakota
Downstream Surface Water Users Study – March 1999

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1.0 Introduction

1.1 Background

Devils Lake is located in a closed basin in northeastern North Dakota. Over the past several years, the lake has risen nearly 25 feet from its 1993 elevation of 1422.5 MSL (feet above mean sea level). The lake is currently at the highest elevations that have been recorded since record-keeping began in 1867, when the lake was at Elevation 1438.4. Above Elevation 1446.6, the lake overflows to Stump Lake. If the lake water elevation were to reach 1459, the combined Devils Lake/Stump Lake system would overflow to the Tolna Coulee and into the Sheyenne River and ultimately to the Red River of the North.

Rising lake levels have affected communities, transportation routes, and rural lands. In 1997, Congress passed Public Laws (PL) 105-18 and 105-62 dealing with an emergency outlet to relieve the flooding at Devils Lake, North Dakota. PL 105-18 authorized the U.S. Army Corps of Engineers (Corps) to do planning, engineering, and design for an outlet and to prepare an Environmental Impact Statement. PL 105-62 set aside funds to initiate construction of an outlet, but final approval was contingent on the Corps reporting to Congress on several issues.

1.2 Purpose and Scope of Downstream Water Users Study

One of the issues of concern to the Corps was the potential impact of the emergency outlet on downstream water users. In response to that concern, the Devils Lake, North Dakota Downstream Water Users Study (Study) (Study; Barr Engineering Co., March 1999) examined the potential water quality impacts and water supply alternatives for users of river water in the Sheyenne River and Red River of the North downstream of the emergency outlet.

The Study centered upon the assessment of possible impacts to downstream river water users associated with operation of an emergency outlet. It addressed potential impacts on, and water supply alternatives for, “consumptive users” of the river water (i.e., municipalities, industries, irrigators, etc. that withdraw water from the Sheyenne River and Red River of the North. The Study identified downstream water users who might be affected by outlet operations, identified water supply alternatives for those adversely affected, and estimated the costs of those alternatives based on expected changes in downstream water quality.

The Study considered permitted and otherwise identifiable municipal, industrial, and agricultural surface water users of the Sheyenne River (from the point of insertion of the Devils Lake outlet releases upstream of Warwick, North Dakota, to the confluence with the Red River of the North) and the Red River of the North (from the confluence with the Sheyenne River to Lake Winnipeg in Manitoba). For the Study, surface water users were divided into the following four categories:

1. Municipal water treatment facilities drawing water from the river.
2. Industrial river water users.
3. Other (untreated) permitted river water users.
4. Non-permitted river water users.

The Study included a separate and distinct analysis of the impacts on users in each category.

1.3 Water Quality Issues

The "Water Quality Impacts" Appendix of the *Emergency Outlet Plan, Devils Lake, North Dakota,* (Corps of Engineers, 12 August 1996) says "The water quality of Devils Lake differs considerably from that of the Sheyenne River and Red River of the North, most notably with respect to its higher salinity and the relative proportion of the major ions."

For the Sheyenne River and the Red River of the North, the principal cations are calcium, sodium, and magnesium, and the principal anions are bicarbonate and chloride, with less than 25 percent of total dissolved solids (TDS) composed of sulfate. In Devils Lake, the principal cation is sodium and the principal anion is sulfate. About 50 percent of the TDS in Devils Lake is sulfate.

Because of the above water quality differences, discharges from Devils Lake to the Sheyenne River (whether from an emergency outlet or natural overflow) will affect downstream constituent concentrations to differing degrees. Upon discharge of water from Devils Lake, the concentrations will generally be highest in the upstream reaches, and lower in the downstream reaches where dilution by tributary and local inflows reduces the effects.

1.4 Changes in the Assumptions Regarding the Emergency Outlet

The downstream impacts from an outlet will be controlled to a large degree by the location, configuration, and operating plan of the emergency outlet. Because the final design and operating plan for the outlet had not yet been determined when the Study was commissioned, preliminary outlet plans had to be used as the basis for the Study. The findings in the Study were, therefore, based on the assumptions in the preliminary Devils Lake emergency outlet design and operating plan (*Devils Lake Emergency Outlet, Independent Assessment, Phase I*, Barr Engineering Co., October 30, 1997). That plan assumed that the location of the outlet would be just south of the City of Minnewaukan, and that the pump station would draw water from the West Bay of Devils Lake.

However, changing the assumptions regarding location and/or operating regime for the pump station would almost certainly result in a change in the downstream river water quality. The water quality of the receiving rivers would be affected by any changes to the assumed design and operating plan that result in pumping more or less water, or in pumping water of different quality than that assumed in the current plan. For example, the location of the pump station might be changed to position it closer to the lake's inflow sources, thus allowing the pump station to send fresher water to the Sheyenne River. Or, the operating limitations on the pump station might be revised to allow a longer operating season each year. Similarly, the water quality criteria applied to the Sheyenne River (criteria that affect the allowable rate of pumping from Devils Lake) might become more or less stringent.

Because the results of the Study were contingent on the trace data (for one potential future lake level scenario) that reflect the water quality in the Sheyenne River and Red River of the North, changes to the assumed outlet design and operating plan for the trace data will change the Study results. Even during the course of the Study, the Corps of Engineers was in the process of evaluating several other alternatives for the emergency outlet design and operation. The results of the analysis of those alternatives were to have been presented in an addendum (to have been produced under Modification 03 of the original Work Order) to the Study.

Ongoing uncertainty regarding the outlet design assumptions, and the likelihood of adjustments to the climate assumptions that formed the foundation for the trace data, eventually caused the production of the Study addendum to be cancelled.

1.4 Purpose and Rationale for this Addendum

At least one aspect of the proposed Study addendum, however, continued to be of interest. The potential effects of an overflow from Stump Lake seemed to merit further consideration. Overflows had not been considered in the original Study, mainly because under the climate assumptions used in producing the trace data, the likelihood of an overflow was seen to be extremely small. The potentially devastating consequences of that overflow, however, seemed worthy of consideration despite what seemed to be a low probability that an overflow would actually occur.

This addendum considers the impacts of an overflow from Stump Lake. For the analysis, attention was focused on a particular overflow trace. It was believed that analysis of one particular trace—despite the fact that the assumptions underlying the trace data are likely to be considered invalid—could prove useful in considering the possible consequences of an overflow. The trace data is therefore used only as an example of the sort of water quality impacts that might be expected as a consequence of an overflow. The data gives an idea of the extremely high water quality constituent concentrations that could be expected when water spills from Stump Lake.

It is acknowledged that updated trace data, or data obtained during an actual overflow event, may or may not produce water quality results similar to those seen in the example overflow trace, or any particular trace. Changing climate assumptions are certain to result in changes in the timing of spills and in predicted constituent concentrations. These changes, however, are not likely to invalidate the general conclusions made regarding the impacts of overflows on downstream water users.

As was the case in the original Study, this addendum describes the potential impacts of the water quality changes on four groups of consumptive water users: municipal water treatment facilities, industrial water users, other permitted water users, and non-permitted water users.

2.0 Overflows from Stump Lake

2.1 Overflow Traces—General

It is impossible to predict with certainty whether or not Stump Lake will overflow into the Sheyenne River. And should it overflow, it is impossible to predict the timing of the overflow – when exactly it would occur, how much water would flow to the Sheyenne River, and for how long the flows would last. Flows might be intermittent or continuous, recurrent or one-time-only, of extended duration or short duration.

2.2 Trace 2415

The Corps provided Trace 2415 as an example of a trace that demonstrates the downstream water quality effects that might be expected as a result of a Stump Lake overflow. Trace 2415 was developed in April 1999 along with other emergency outlet scenarios, as described in the *Draft Main Report Addendum of the Devils Lake Limits Study* (Barr Engineering Company, July 1999). Examination of Trace 2415 gives an idea of the sort of issues that might be encountered should the lake spill into the Sheyenne River.

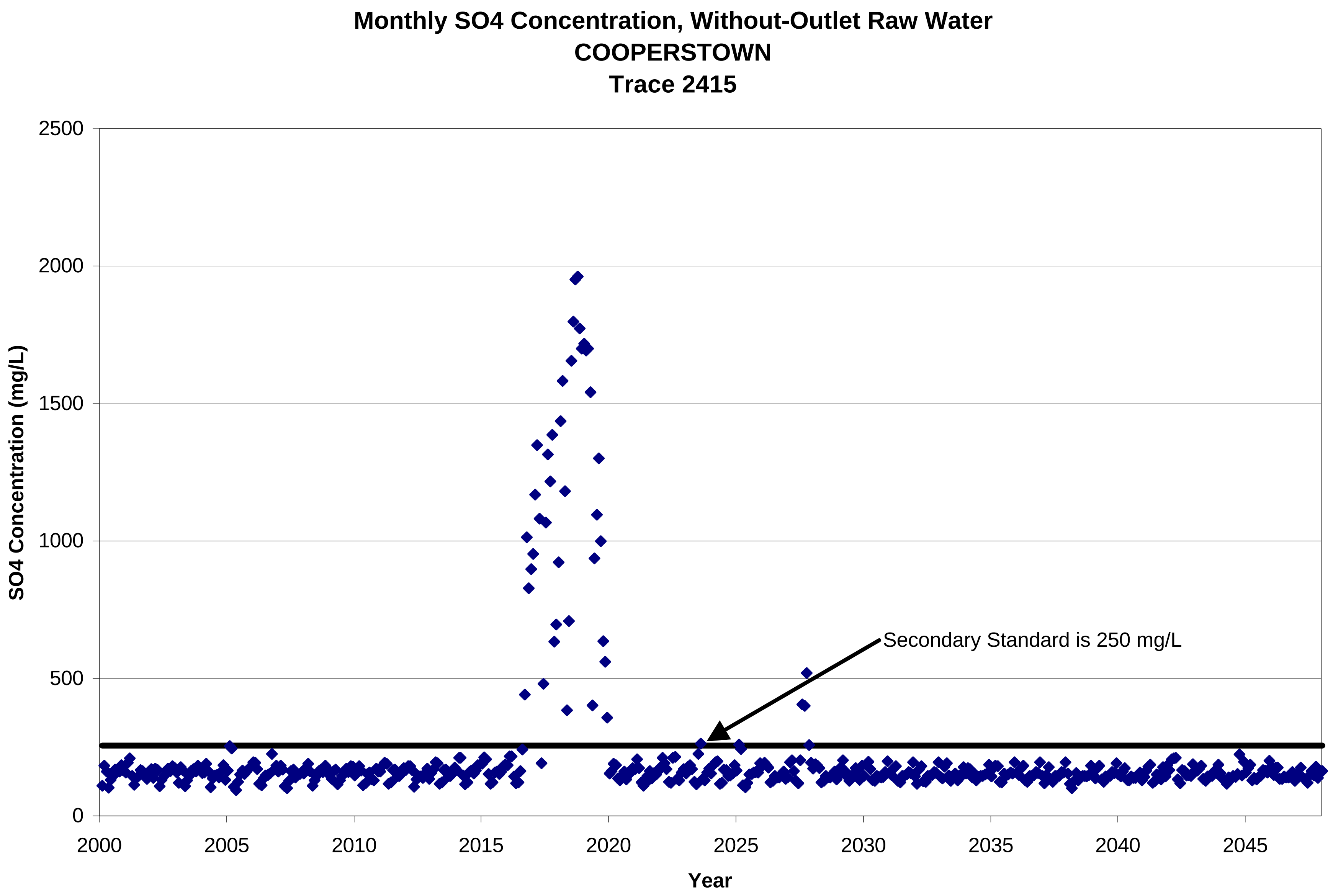
Figure 1 (all figures and tables for this addendum are provided at the end of the section in which they are referenced), showing the projected monthly average sulfate concentrations at Cooperstown, gives a general idea of the how the overflow would occur under the assumptions of Trace 2415. Cooperstown is the furthest upstream of the Corps' water quality "stations" used to track projected water quality in its HEC-5Q model for the Sheyenne River and the Red River of the North.

On Figure 1, monthly average sulfate concentrations above the normal range indicate that an overflow of high-sulfate water from Stump Lake has occurred. Overflows of limited extent and duration are seen in years 2023, 2027 and 2028. Most of the overflow, however, occurs beginning in year 2016 and continues intermittently through 2020 (with minor overflows in 2021 and 2022). Figure 1 shows the sulfate concentrations at Cooperstown returning to normal after about 2023.

This overflow pattern—with a significant and extended overflow occurring during the years 2016 through 2020, and lesser overflows in other years – is seen in the other constituent concentration predictions for Cooperstown. The pattern is also repeated in the traces for all stations downstream.

As would be expected, the effects of the increased dissolved solid load from Stump Lake are diminished downstream. Inflowing tributaries to the Sheyenne River and the Red River of the North dilute the streams, and reduce the constituent concentrations at downstream stations. Compare, for example, Figure 1 with Figure 2, which shows the sulfate concentrations at Halstad, downstream of the confluence of the Sheyenne with the Red River of the North. Peak sulfate concentrations at Halstad (approximately 810 mg/L) are greatly reduced by comparison with those at Cooperstown (approximately 1,950 mg/L). Projected constituent concentrations for Trace 2415 at Emerson (approximately 340 mg/L—see Figure 3) show that the effects of the Stump Lake overflow are greatly diminished by the time the Red River of the North crosses the Canadian border.

As has been mentioned, the timing and extent of the Stump Lake overflows would be different for other traces and for other climate assumptions. However, the general pattern of diminished impacts further downstream can be expected to occur under any modeling scenario. This pattern will repeat itself as the overflow plume is carried downstream and gradually diluted.



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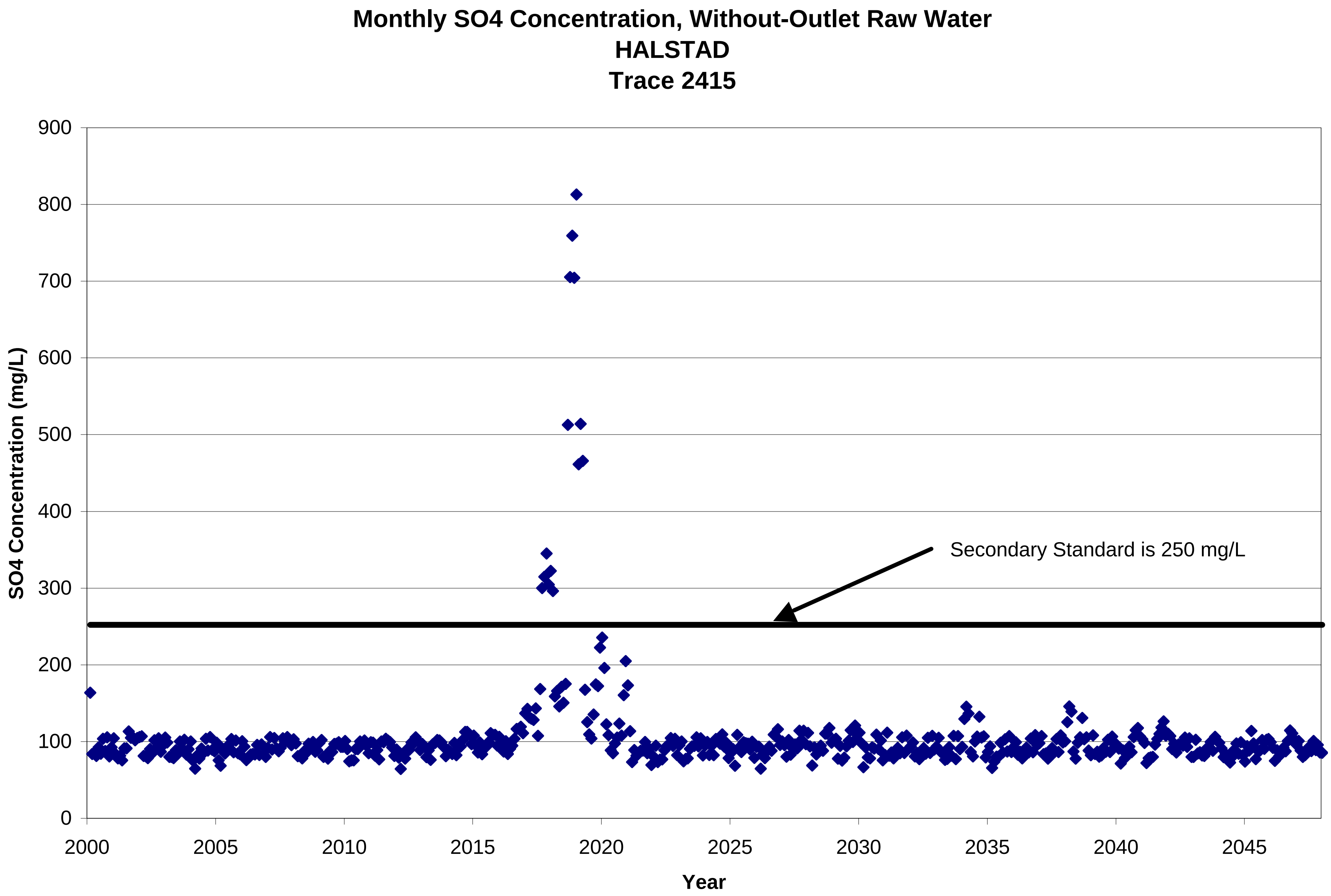

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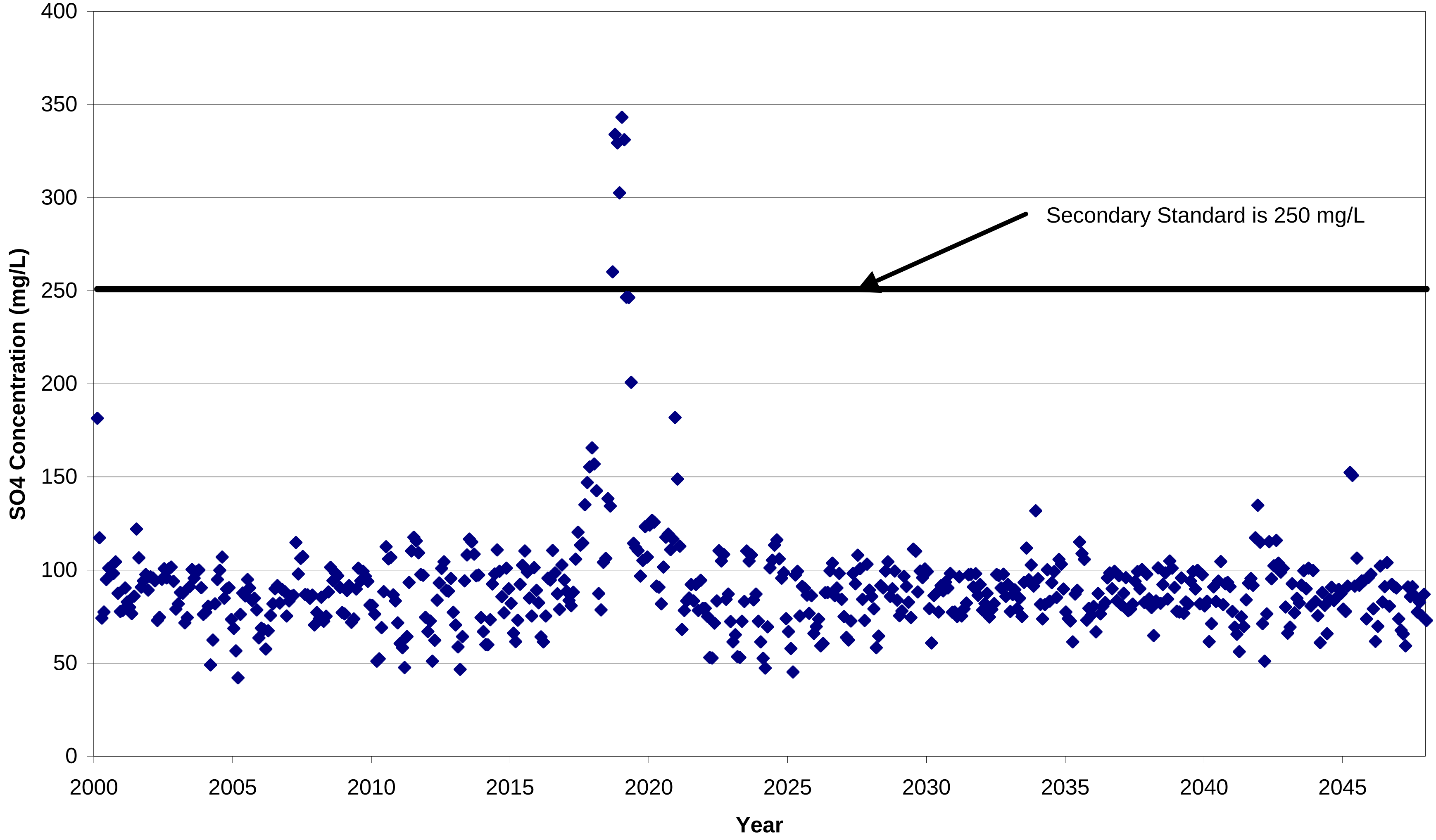
Monthly SO4 Concentration, Without-Outlet Raw Water
EMERSON
Trace 2415



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3.0 Municipal Water Treatment During a Spill

Should Stump Lake overflow, one of the principal concerns will be how to continue to supply safe and aesthetically acceptable drinking water to the communities that draw water from the Sheyenne River and the Red River of the North. This issue is addressed in the sections that follow.

3.1 River Water Quality for Trace 2415

Table 3-1 gives an idea of the water quality that would be experienced (for Trace 2415) at the municipal water treatment facilities (MWTFs) along the Sheyenne River and the Red River of the North. For each of the MWTFs, Table 3-1 shows the approximate peak monthly average concentration that occurs during the 2016-2023 overflow period. A “normal range” for the monthly average values was computed, and is listed in Table 3-1. For this analysis, the normal range was defined as being two standard deviations above and below the mean value for the 50-year period. In computing the mean and standard deviation, data from the principal Stump Lake overflow period for Trace 2415 (2016 through 2023) were excluded. The table also shows the number of months during the 7-year Stump Lake overflow period in which the constituent concentration is outside of (above) the normal range.

Examination of the data presented in Table 3-1 allows several conclusions to be drawn:

- As would be expected, the MWTFs furthest upstream would experience the most severe deterioration in water quality during an overflow from Stump Lake. The Sheyenne River as it passes Valley City and Fargo, and the Red River of the North as it flows by Grand Forks, show extremely high peak water quality constituent concentrations. These concentrations are far in excess of existing secondary standards, and would not be manageable with existing treatment facilities.

- Further downstream, at the MWTFs at Grafton, Drayton, Pembina, Letelier, and Morris, the water quality constituent concentrations are much less extreme during an overflow. The less extreme concentrations are apparently due to dilution effects – near Grand Forks, several large and small tributaries bring less concentrated water to the flows in the Red River of the North. Peak concentration values exceed the secondary standards for TDS and sulfate, but by much smaller amounts than at the upstream MWTFs. The monthly averages for sodium at the downstream MWTFs never exceed pertinent guidelines.

- Not only do the five downstream MWTFs experience lower peak monthly concentrations resulting from a spill from Stump Lake, but they also experience a shorter period during which the normal concentration ranges are exceeded. While Valley City, Fargo, and Grand Forks must contend with extremely high constituent concentrations for 40 to 50 months (during the 50-year projection), the downstream MWTFs will experience high concentrations for only 20 to 30 months, and in some cases, for less than 10 months.

3.2 Water Quality Issues of Concern

During a spill from Stump Lake, the sharply elevated water quality constituent concentrations that might be experienced (see Table 3-1) would be of significant concern to MWTF operators and local decision-makers. This is particularly true at the three furthest upstream MWTFs – Valley City, Fargo, and Grand Forks. Further downstream, at the Grafton, Drayton, Pembina, Morris, and Letelier MWTFs, constituent concentrations are modulated by the dilution provided by major and minor tributaries to the Red River of the North.

The U.S. EPA sets both enforceable (Maximum Contaminant Limits—MCLs) and non-enforceable health goals for water treatment. The enforceable standards are known as primary standards, and the secondary standards are known as secondary standards. Primary standards are designed to protect public health. By contrast, the secondary standards are concentrations for drinking water that, when exceeded, may affect the taste, odor, or other aesthetic aspect of the water.

None of the modeled water quality constituents for Trace 2415 have a primary standard, though secondary standards exist for two (TDS and sulfate) of the constituents. A World Health Organization (W.H.O.) standard is also in effect for sodium, and an EPA guidance level for an at-risk population was also identified for sodium. Each of the modeled water quality constituents may also be of concern with respect to the aesthetic quality of the water.

Water treatment issues related to each of the modeled water quality constituents are summarized below:

- **Total Hardness—**"Hardness" refers to the quantity of calcium and magnesium salts in water. There is no primary EPA standard for drinking water; there are no negative health effects associated with hard water. Water having greater than 150 mg/L total hardness is generally considered hard, while water with less than 75 mg/L is generally considered “soft”. Hard waters in distribution systems can cause scaling in pipes, and can react with soap to reduce its cleansing effectiveness. Hardness is usually removed from water by softening; all of the MWTFs along the Sheyenne River and the Red River of the North soften their water as part of their normal water treatment processes.

- **Non-carbonate hardness—**This is the portion of the dissolved calcium and magnesium ions that are associated not with carbonate, but with sulfate and chloride. Non-carbonate hardness is therefore also referred to as permanent hardness, because traditional softening processes remove only carbonate hardness.

- **TDS—**TDS is the measure of dissolved inorganic substances in water. Taste and odor problems with water derive from several sources, among which is the TDS concentration. The secondary standard for TDS is 500 mg/L. Generally, waters with a TDS less than 1,200 are acceptable, though levels less than 650 mg/L are preferable. Because calcium and magnesium salts comprise a part of TDS, softening reduces TDS. Complete removal of TDS, however, generally requires expensive treatment such as demineralization by ion exchange or reverse osmosis. Because of the high cost of such treatment, it is usually not done for drinking water.

- **Sulfate—**The secondary standard for sulfate is 250 mg/L. A high sulfate level causes undesirable taste and odor in drinking water, and has undesirable health effects. High concentrations of sulfate can cause transitory diarrhea. Sulfate is not readily removed with traditional drinking water processes.

- **Sodium—**High sodium intake has been associated with high blood pressure and heart disease. Although the U.S. EPA has no secondary standard for sodium in drinking water, it sets a “guideline” of 20 mg/L for an at-risk population—those suffering from diseases that may be aggravated by a high sodium intake. The W.H.O. lists a value of 200 mg/L as a recommended maximum for sodium concentrations in drinking water.

- **Chloride—**The EPA’s secondary standard for chloride is 250 mg/L. Concentrations above this standard may give water a salty taste. Also, high chloride concentrations can accelerate corrosion of metals within the water distribution (piping) system. As is the case with sulfate, chloride is not readily removed with traditional water treatment processes.

3.3 Decision-Making for the MWTFs

Water quality constituent concentrations experienced during an overflow (Table 3-1) from Stump Lake will be significantly higher than those currently experienced in the Sheyenne River and the Red River of the North, and significantly higher than those resulting from controlled pumping from Devils Lake. However, the elevated concentrations may be experienced only briefly and intermittently. The example trace (2415) used in this analysis shows a primary period (2016 through 2020) where water spills from Stump Lake, with minor spills occurring in other years. And even during the primary spill period, water flows from Stump Lake only during some months of the year. During the remainder of the period modeled for Trace 2415, the Sheyenne River (and the Red River of the North) will show constituent concentrations largely unaffected[1] by Devils Lake.

The timing and extent of a Stump Lake overflow is unpredictable. It is likely that MWTF operators will have only a few days or weeks to react when high-TDS water begins to spill, although they are likely to be aware of an imminent overflow some months in advance of the actual spill. Furthermore, should a spill occur, it would be impossible to predict whether the spill will last for days, weeks, months, or years. Given this uncertainty, it is impossible to determine in advance the response of MWTF operators and other decision-makers. These responses are likely to depend on several factors, including:

- Short- and long-term weather forecasts and corresponding Stump Lake flow predictions.
- The amount of warning and preparation for a spill that decision-makers have had.
- The relatively recent spill history. For an initial spill, operators may adopt a wait-and-see approach to the problem. If there has been generally continuous flow from Stump Lake over a period of one to two years, however, decision-makers may take a more aggressive approach to dealing with the problem.

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[1] Some residual effects of a Stump Lake spill can be expected even after flow from the lake has ceased. Lake Ashtabula on the Sheyenne River will function as a reservoir for high TDS water released from Stump Lake. Natural flushing of Lake Ashtabula will eventually return that lake and downstream river reaches to normal TDS concentrations, but full recovery will be gradual and slow.

- The decision-makers' perception of the degree of concern of the local citizenry.
- The amount of local, state, or federal support available for mitigative measures, treatment plant improvements, alternative treatment technologies, etc.
- Availability of alternate water supplies at the time of the spill.
- Individual MWTF capacities and capabilities for handling high-TDS water

Based on consideration of the above factors, each MWTF is likely to respond in its own way to an actual or imminent Stump Lake spill. For each of the affected communities, a public education campaign would be of value in informing the citizens of the local plans for dealing with the source water quality changes, addressing health and public safety concerns, and providing for the distribution of bottled water.

3.4 Ion Exchange Treatment in Response to an Overflow

Neither lime-soda ash softening nor any of the other treatment processes currently employed at the water treatment facilities remove sulfate, chloride, or sodium. One option available for removal of these compounds is water treatment using ion exchange. Ion exchange treatment can remove nearly all dissolved substances from raw water supplies, so it can be an effective way to bring TDS, sulfate, and sodium concentrations down to acceptable levels.

The possibility of using ion exchange to treat river water was addressed in the context of Phase II treatment of river water in the March 1999 report. Ion exchange treatment may also be an option for dealing with the high concentrations of dissolved substances in the river water following an overflow from Stump Lake. The uncertainty regarding the severity and duration of an overflow may make installation of ion exchange treatment equipment especially attractive. Given the extremes in raw water quality that an overflow may bring, ion exchange treatment at the MWTFs may be one of the few means available for providing consistently acceptable finished water quality.

However, ion exchange treatment is likely to be a relatively expensive option for providing safe and aesthetically acceptable drinking water for the communities affected by an overflow. Examination of Trace 2415 data suggests, nevertheless, that for the cities of Valley City, Fargo and Grand Forks, ion exchange may provide a reasonable approach to dealing with the overflow. For communities farther downstream - Grafton, Drayton, Pembina, Letellier, and Morris – the lower peak constituent concentrations and smaller period of concern would probably reduce the likelihood of accepting in the high cost of ion exchange treatment technology. The approximate costs of providing ion exchange treatment are given in subsequent sections of this report. Costs are provided only for Valley City, Fargo, and Grand Forks; it is assumed that the communities further downstream would not utilize ion exchange in dealing with an overflow.

Assumptions regarding the development of the ion exchange capital and O&M costs for this addendum are as follows:

Ion exchange almost completely removes the ions in the water and, therefore, only a portion of the total water supplied to the users would be required to undergo ion exchange treatment. (Based on estimates of the raw water TDS concentrations, sections below - addressing each of the MWTFs - list the percent of the total raw water supply that is assumed to need treatment with ion exchange.) The ion-free finished water stream from the process would then be blended with the stream from the existing treatment processes. In this manner, a blended finished water could be produced that would be similar to that of the pre-overflow conditions.

To reduce operational costs, ion exchange could also be used to provide only enough water to meet the consumptive needs of each community. Capital costs would not be substantially reduced, however, and a means would have to be found to distribute the drinking water. For these reasons, this drinking-water-only use of ion exchange is not addressed in this addendum.

Capital costs for ion exchange processes were developed using the USEPA document *Estimation of Small System Water Treatment Costs* (R.C. Gumerman, et. al. USEPA, 1994). This documents focuses on treatment facility sizes ranging from 2,500 gallons per day (gpd) to 1 million gallons per day (MGD). The items included in the capital cost curves include:

- Excavation and Site Work
- Manufactured Equipment
- Concrete
- Steel
- Labor

- Piping
- Valves
- Electrical and Instrumentation
- Housing

A contingency is also included as part of the capital costs. A best-fit analysis was performed on the data used to develop the cost curve.

The size and capacity of the ion exchange unit depends on the flowrate and the TDS concentration of the water fed into the unit. The amount fed to the unit will be a fraction of the total treatment facility flow, but will be related to the overall demand at the plant. Therefore unit sizing and associated costs were based on the highest TDS concentration and the average annual water demand. The estimated capital cost was updated from 1983 dollars to 1998 dollars (as was done for the March 1999 study) by multiplying the result by the 1998 to 1983 ratio of Construction Cost Index (CCI) published by Engineering News Record.

The same sources and methods were relied upon to develop the O&M costs for ion exchange. The items included in the O&M cost curves include:

- Energy
- Maintenance Material
- Regeneration Chemical costs
- Labor

Cost estimates do not include the costs that may be associated with the disposal of the brine that results from regeneration of the ion-exchange resin. It was assumed that the brine would be discharged to the sanitary sewer collection systems (see also the memo: *Devils Lake Downstream Users Study, Mod 3: Brine Disposal Alternatives*, Barr Engineering Company, March 15, 1999). The assumed labor, energy and chemical costs for ion exchange treatment are the same as those assumed in the March 1999 report. The reader is referred to that report for the details of the cost assumptions.

Because the amount of TDS needed to be removed varied from month to month and from facility to facility, the O&M costs were developed on a per-pound-of-TDS-removed basis for the various treatment facilities. The values were plotted and a cost curve was developed for per-pound cost for TDS removal versus treatment facility system size. A best-fit analysis of the curve was performed. The total pounds of TDS removed were estimated by calculating the total flow for the overflow period and estimating the average TDS concentration for the overflow period.

The capital cost for ion exchange was assumed to be incurred in the first year of operation. Because the duration of the overflow predicted by Trace 2415 was relatively short, it is assumed that no equipment replacement would be required. The O&M costs for the duration of the overflow were not were not brought back to present worth values.

3.5 Individual MWTFs and Trace 24155

The following sections give brief descriptions of each of the MWTFs along the Sheyenne River and the Red River of the North, and explain the current water supply situation at each of the facilities. The facilities are considered in order, from upstream to downstream; facilities furthest upstream will experience the most dramatic impacts should there be an overflow from Stump Lake.

For each MWTF, options for dealing with a spill are discussed. In listing the options that may be considered, it is assumed that the MWTFs will be searching for the most cost-effective means to provide safe and palatable drinking water to the community.

3.5.1 Valley City

The Valley City Public Works Water Treatment Facility was built in 1972, and has a capacity of 4.0 million gallons per day (MGD). The facility serves a population of 7,400 people with an average water usage of 1.0 MGD. During most of the year, the raw water source is the Sheyenne River. During summer months, due to taste and order problems resulting from elevated algae levels in the river, raw water is instead obtained from shallow wells located adjacent to the river. However, the wells are only 48 feet from the river. Therefore, despite the wells' ability to exclude algae, it is unlikely that the well water quality (in terms of TDS levels) would be substantially better than that of the river water.

Because it is furthest upstream, Valley City can be expected to experience the most severe deterioration in raw water quality (see Table 3-1) should an overflow occur. Trace 2415 data indicates that the TDS concentrations at Valley City would peak at nearly 4,000 mg/L. Sulfate concentrations would reach nearly 2,000 mg/L (nearly eight times the secondary standard) and total hardness concentrations would peak at nearly 1,000 mg/L. Given these extremely high constituent concentrations, the city could not meet the secondary standards (for TDS, sulfate, or sodium) using their existing facility and equipment. The softening process would diminish the TDS concentration somewhat, but sulfate and sodium concentrations would not be reduced. Finished water would have taste and odor problems, and would pose health risks to at-risk individuals. The city would therefore have to turn to alternate means for providing safe and palatable water to the residents. Several options may be considered:

- An attempt may be made to use the city's existing wells to provide the entire raw water supply. Based on the information obtained from the city, it is likely that with both wells operating the city could meet the maximum water demand. The water quality from the wells may be somewhat better than that taken directly from the Sheyenne River, and may be treatable to acceptable hardness and TDS levels. Sulfate and sodium levels, however, are likely to remain problematic because these substances are not removed by standard softening methods.

  Costs for increased use of the city's existing wells are not likely to be great. The increased softening costs for treating the pumped water were not evaluated for this study.

- Residents may be asked to use bottled water for their drinking and cooking water needs and continue to use treated (but high in hardness, TDS, etc.) Sheyenne River water or well water for non-consumptive uses. The non-consumptive uses include lawn-watering, toilet, bathing, laundry, dish washing, etc. Provision of bottled water could be the responsibility of the MWTF, state or local agencies, or the residents themselves.

  A bottled water supplier (Culligan) estimates that bottled water could be supplied to the city's residents for approximately $0.25 per gallon. Based on an average consumptive use of 6.5 gallons per person per day, the monthly cost for supplying the city with bottled drinking water would be approximately $12,000.

- If decision-makers anticipate that the overflow will be of long duration, they may seek water from an area aquifer that would not be affected by the Stump Lake overflow. The nearest usable groundwater source is the Spiritwood Aquifer, some 18 miles away. (Application to local rural water supply companies is likely to be fruitless. The rural water supplier in the area was contacted, but reports that the company has insufficient capacity to serve a city the size of Valley City.) Construction of two wells and an 18-mile pipeline would be required to allow Valley City to use water from the Spiritwood Aquifer. The estimated cost for installation of two wells and a pipeline is approximately $6 million.

- If decision makers for Valley City anticipate that the Stump Lake overflow will be of long duration, installation and operation of ion exchange equipment may be considered. Capital and O&M costs for an ion exchange treatment process were estimated using the cost curves discussed in Section 3.4. Based on examination of Trace 2415, it was estimated that the overflow would affect Valley City's raw water quality for a five–year period. It was assumed that the ion exchange unit would operate during that entire period. Based on the assumption that 85 percent of Valley City's water would require treatment with ion exchange, the capital cost for this system was estimated to be $480,000. The O&M cost for the five-year treatment period was estimated to be $7,250,000.

3.5.2 Fargo

The Fargo Water Treatment Facility was constructed in 1997 and currently serves a population of approximately 85,000. The facility has a peak rated capacity of 30 MGD and an average rated capacity of 14 MGD. The average daily water use has been approximately 11.5 MGD.

Fargo has its primary intake source on the Red River of the North and a secondary intake source on the Sheyenne River. The intake on the Red River of the North is located upstream of the confluence with the Sheyenne River. Therefore, should Stump Lake overflow it would not have an effect on the raw water drawn from the Red River of the North. The Fargo treatment facility also has a permit to withdraw water from Lake Ashtabula in case of water scarcity.

Like Valley City, Fargo can be expected to experience severe deterioration in raw water quality (at its secondary intake on the Sheyenne River - see Table 3-1) should an overflow occur. Trace 2415 data indicates that the TDS concentrations for the Sheyenne River at Fargo would peak at approximately 3,300 mg/L. Sulfate concentrations would reach approximately 1,600 mg/L (six times the secondary standard) and total hardness concentrations would peak at nearly 900 mg/L. Were the city to continue using Sheyenne River water during overflow periods, it would not be able to meet the secondary standards (for TDS, sulfate, or sodium) using the existing facility and equipment. Finished water would have taste and odor problems, and would pose health risks to at-risk individuals.

Options for Fargo may include:

- During overflow periods, Fargo could attempt to rely entirely on the primary Red River of the North intake for its raw water supply. Water quality in the Red River of the North (where it would be withdrawn, upstream of the confluence with the Sheyenne) is normally relatively poor, but it is likely to be significantly better than that in the Sheyenne River during an overflow.

- Fargo may continue using water from its two river sources, attempting to increase its softening treatment to reduce hardness to acceptable levels. Sulfate and sodium levels are not likely to be reduced significantly, however, through this effort. Bottled water would probably have to be provided for non-consumptive uses. The estimated monthly cost for providing bottled drinking water for Fargo is $138,000.

- If decision-makers for Fargo anticipate that the overflow will be of long duration and are mistrustful of the reliability of the water quality in the Red River of the North, ion exchange may be considered. Ion exchange costs for Fargo were developed assuming that only the portion of water drawn from the Sheyenne River would be treated using ion exchange. Based on Trace 2415, it was estimated that the overflow would affect Fargo's water supply for a five–year period. The ion exchange unit was assumed to operate during that entire period. Based on the assumption that 83 percent of Fargo's water would require treatment with ion exchange, the capital cost for this system was estimated to be $410,000. The O&M cost for the five-year treatment period was estimated to be $4,674,000.

3.5.3 Grand Forks

The City of Grand Forks Water Treatment facility was built in 1897, but has undergone many upgrades over the years. The facility has a capacity of 16.5 MGD but produces an average of approximately 8.0 MGD. The facility serves approximately 55,000 people.

Grand Forks draws approximately 60 percent of their raw water from the Red Lake River and approximately 40 percent from the Red River of the North. Water from the two sources is blended, with the exact proportions depending on the water quality in each river. The elevated total organic carbon (TOC) concentrations in the Red Lake River make it an undesirable raw water source at certain times of the year.

During a Stump Lake overflow, the dilution provided by the Red River of the North and its tributaries causes the water quality at Grand Forks to be better than that of the Sheyenne River at Fargo. Nevertheless, Grand Forks is likely to experience substantial deterioration in its raw water quality (see Table 3-1). Trace 2415 data indicates that the TDS concentrations for the Red River of the North at Grand Forks would peak at approximately 1,800 mg/L. Sulfate concentrations would reach approximately 800 mg/L and total hardness concentrations would peak at nearly 600 mg/L.

It is likely that the MWTF at Grand Forks would reduce its reliance on the raw water from the Red River of the North during overflow periods. Using the Red River of the North water along with the city's existing facility and equipment would mean that the secondary standards (for TDS, sulfate, or sodium) would not be met. Finished water would have taste and odor problems, and would pose health risks to at-risk individuals.

Options for dealing with a Stump Lake overflow at Grand Forks might include:

- Relying entirely on the Red Lake River for the MWTF's raw water source. This option may be viable during periods of low water demand, provided that Red Lake River TOC levels are not unacceptably high. This option would result in increased softening treatment costs to the city, because the Red Lake River water is harder than the water normally drawn from the Red River of the North. The increased costs were not estimated for this study.

- Continuing to use both rivers as raw water sources, providing additional softening to reduce hardness as much as possible, and providing bottled water for non-consumptive uses. This option will be required if the Red Lake River cannot be used as the sole source for raw water. (The scarcity of suitable local groundwater resources makes it highly unlikely that local or regional wells could provide a substitute raw water supply for Grand Forks.) Costs for providing bottled water to city residents would be approximately $89,000 per month.

- Should it be determined that the Red Lake River cannot be used as the sole source for raw water, construction of an ion exchange treatment system to treat the water from the Red River of the North may be considered. Ion exchange costs for Grand Forks were developed assuming that only the portion of water drawn from the Red River of the North would be treated with ion exchange. Based on examination of Trace 2415, it was assumed that the overflow would affect Grand Forks raw water supply for approximately three and one-half years. The ion exchange unit was assumed to be operating during that entire period. Based on the assumption that 40 percent of Grand Fork's water comes from the Red River of the North and that only 60 percent of that water would require treatment with ion exchange, the capital cost for this system was estimated to be $990,000. The O&M cost for the five-year treatment period was estimated to be $2,866,000.

3.5.4 General Note on Overflow Water Quality at Grafton and Points Downstream

At Grafton and at all points downstream of Grafton, the dilution provided by the Red River of the North and its tributaries causes overflow-related water quality deterioration to be greatly reduced. Peak water quality constituent concentrations, while still elevated by comparison to the normal ranges (see Table 3-1) are approximately one third to one fifth of those seen at Valley City. In addition, Trace 2415 data shows that the number of months during which the overflow causes water quality to exceed the normal range (Table 3-1) is greatly reduced by comparison to points upstream. As a result, at Grafton and points downstream, dealing with the water quality issues resulting from a Stump Lake overflow can be expected to be much less problematic for MWTF operators than it would be at Valley City, Fargo, or Grand Forks.

Trace 2415 data is similar for Grafton, Drayton, Pembina, Morris, and Letelier. The trace data indicates that the TDS concentrations for the Red River of the North would peak at approximately 900 mg/L. Sulfate concentrations would reach approximately 340 mg/L and total hardness concentrations would peak at approximately 400 mg/L.

These peak concentrations will require some adjustment of the treatment regime, but may not present extreme difficulties for the affected communities. The total hardness, while elevated, can be brought down to acceptable levels by increased application of softening chemicals. Reducing the hardness is likely to bring the TDS levels down to within the secondary standard maximum of 500 mg/L for most of the time during the overflow periods.

Secondary standards for sulfate are not likely to be met during the peaks of the overflow periods, but the moderately elevated sulfate concentrations may not be noticeable, and may provide no more than a temporary inconvenience to local residents. Increased consumption of bottled water by at-risk individuals during the high-sulfate periods is likely to be sufficient for controlling any ill effects.

During an overflow, sodium peak concentrations for these communities are expected to remain well within the W.H.O. guidance level of 200 mg/L. The EPA's recommended maximum sodium concentration (20 mg/L) for at-risk individuals will be continuously exceeded, but this will not represent a change from the normal situation in these communities.

3.5.5 Grafton

The Grafton Water Treatment Facility was installed in 1954 and serves 5,000 people. The facility has a capacity of 3.0 MGD and an average daily water usage of 0.7 MGD.

Approximately 90 percent of the facility's raw water supply comes from the Red River of the North and 10 percent from the Park River. According to the personnel at the City of Grafton, the Park River typically has a substantially higher total hardness concentration than the Red River of the North, so that the Red River of the North is generally the raw water source of choice.

Grafton may deal with a Stump Lake overflow in one of the following ways:

- Grafton may deal with the overflow mainly by using its existing equipment to reduce the hardness, simply by increasing the chemical feed rates. This approach may be effective, because the raw water hardness during an overflow will be increased only moderately (see Table 3-1) by comparison to the normal range. Chemical costs and sludge disposal costs would be increased. Bottled water may need to be provided to at-risk individuals. Bottled water costs in the Grafton area are likely to be approximately $0.30 per gallon.

- Because Grafton is able to draw water from the Park River, the city may attempt to meet its water demands during an overflow by withdrawing water exclusively from the Park River. However, the hardness levels in the Park River are significantly greater than those of the Red River of the North. Depending on the actual situation at the time of the overflow, it may be more cost-effective to continue using water from the Red River of the North.

3.5.6 Drayton

The Drayton Water Treatment Facility was constructed in 1962, with expansions and upgrades occurring in 1994, 1995, and 1996. The city uses the Red River of the North as its raw water source and serves a population of approximately 1,000 people. The maximum capacity of the facility is 0.72 MGD and the average raw water intake is 0.25 MGD.

The Red River of the North is the sole raw water source for Drayton; the city has no nearby rivers to draw from, and Drayton is in an area with virtually no usable groundwater. For Drayton, options for dealing with a Stump Lake overflow are somewhat limited:

- Like Grafton, Drayton may deal with the overflow mainly by using its existing equipment to reduce the hardness, simply by increasing the chemical feed rates. This approach may be effective, because the raw water hardness at Drayton during an overflow will be increased only moderately by comparison to the normal range. Chemical costs and sludge disposal costs would be increased. Bottled water may need to be provided to at-risk individuals. Bottled water costs in the Drayton area are likely to be approximately $0.30 per gallon.

- It may be possible for Drayton to obtain water from a rural water supplier. North Kittson Rural Water, based out of Lake Bronson, Minnesota, has already performed a feasibility study to estimate the cost for Drayton to use North Kittson Rural Water as their entire water supply. The feasibility study indicates that the billing rate would be approximately $1.00 per 1,000 gallons, or approximately $92,000 per year based on an average community water use rate of 0.25 MGD.

3.5.7 Pembina

The City of Pembina currently serves approximately 650 people, and uses the Red River of the North as its raw water supply. The water treatment facility was constructed in 1970 and has a maximum capacity of 0.85 MGD. The average water use is only 0.17 MGD.

Like Drayton, Pembina has the Red River of the North as its sole raw water supply. Pembina's approach to dealing with deteriorated water quality resulting from a Stump Lake overflow might involve:

- Using its existing equipment to reduce the hardness, simply by increasing the chemical feed rates. This approach may be effective, because the raw water hardness at Pembina during an overflow will be increased only moderately by comparison to the normal range. Chemical costs and sludge disposal costs would be increased. Bottled water may need to be provided to at-risk individuals. Bottled water costs in the Pembina area are likely to be approximately $0.30 per gallon.

- Connecting to a rural water supplier. North Valley Water Association provides rural water in the area and already has a pipeline to Pembina. The area of Pembina has virtually no usable ground water, so wells are not an option.

  Based on conversations with an Association representative, connection to the North Valley Water Association would cost approximately $800,000 for past and future improvements. The representative indicated that the billing rate to Pembina residents would be approximately $1.50 per 1,000 gallons or approximately $95,000 annually, based on the community's average annual water usage of 0.17 MGD.

3.5.8 Letellier

Letellier is located in Manitoba, Canada, approximately 10 miles north of the United States-Canadian border. The Letellier water treatment facility serves the entire surrounding county, and the facilities average daily finished water output is approximately 1.0 MGD. A private Canadian company operates the City of Letellier's water treatment facility.

The city currently draws its raw water from the Red River of the North, and has no alternate raw water source. Letellier's options for dealing with deteriorated water quality resulting from a Stump Lake overflow are likely to include:

- Using its existing equipment to reduce the hardness, simply by increasing the chemical feed rates. This approach may be effective, because the raw water hardness at Letellier during an overflow will be increased only moderately by comparison to the normal range. Chemical costs and sludge disposal costs would be increased. Bottled water may need to be provided to at-risk individuals. Bottled water costs in the Letelier area are likely to be approximately $0.30 per gallon.

- Obtaining water from regional surficial aquifers. Letellier currently supplies finished (Red River) water to area towns; Letellier is in effect the rural water supplier for the area, so that it would not be able to obtain water from a rural water supply company. Installation of two wells into a nearby aquifer, and construction of the required 10 miles of pipeline is likely to cost approximately $3.4 million.

3.5.9 Morris

The City of Morris is located in the province of Manitoba and uses raw water from the Red River of the North to serve a population of approximately 1,700 people. The average water usage was reported to be 0.73 MGD. The same private Canadian company that operates Letellier's facility operates Morris's water treatment facility.

Morris uses the Red River of the North as its sole raw water supply. Options for Morris are likely to similar to those for Letellier:

- Using existing equipment to reduce the hardness, simply by increasing the chemical feed rates. This approach may be effective, because the raw water hardness at Morris during an overflow will be increased only moderately by comparison to the normal range. Chemical costs and sludge disposal costs would be increased. Bottled water may need to be provided to at-risk individuals. Bottled water costs in the Morris area are likely to be approximately $0.30 per gallon.

- Obtaining water from regional surficial aquifers. Assuming that two wells would be required, along with 13 miles of pipeline, the capital costs for providing well water to the city would be approximately $3 million.

3.6 Summary and Discussion

When considering the findings of this analysis, it should be continuously kept in mind that the conclusions presented pertain mainly to Trace 2415. That trace represents only an example of what might occur should Stump Lake overflow. It is impossible to predict whether or not an overflow will occur—but should it occur, there are a nearly infinite number of possibilities for just how and when the spill would take place.

Trace 2415 shows spilling from Stump Lake occurring on and off during the 50-year period of the trace, but occurring primarily during the period 2016 to 2023. Intermittently during this period, the spill results in extremely high water quality constituent concentrations in the Sheyenne River, and high constituent concentrations in the Red River of the North. As would be expected, dilution causes the effects to be less severe for the MWTFs farthest downstream. But the elevated constituent concentrations will certainly be of concern to all of the MWTFs and the communities that they supply.

Just as it is impossible to predict the timing or duration of a Stump Lake spill, so is it impossible to predict the reaction of the decision-makers controlling the affected MWTFs. How each MWTF deals with a spill will depend on many factors. These factors will include the location of the MWTF, the potential for obtaining an alternate raw water supply, community pressures, and the amount of financial resources available.

It is almost certain that the MWTF at Valley City will be the most adversely affected by an overflow. Of all the MWTFs, Valley City will experience the highest raw water constituent concentrations. Furthermore, Valley City's alternative raw water supply options are not likely to be satisfactory. Its existing surface water wells are not likely to provide water of substantially better quality than that of the Sheyenne River, and obtaining water from the nearest surficial aquifer is likely to be prohibitively expensive. During overflow periods, Valley City's MWTF can improve the river water quality by softening and disinfection so as to make it useable for non-consumptive uses. An alternate drinking water supply will need to be provided for the residents.

At Fargo and Grand Forks, the situation is likely to be somewhat better. The raw water, diluted by adjoining streams, will show constituent concentrations that are less extreme—though still greatly in excess of applicable standards. Using the current raw water supplies and existing treatment operations, the Fargo and Grand Forks MWTFs will not be able to meet applicable secondary standards. Each of the two cities has an alternate water supply source that while not ideal, may be successfully utilized during Stump Lake overflow periods. Providing bottled water for consumptive use, however, may also be necessary during these periods.

Farther downstream, at the MWTFs at Grafton, Drayton, Pembina, Morris, and Letelier, Trace 2415 indicates that dealing with the effects of an overflow may be much less problematic. Dilution by low-TDS tributaries upstream of these communities results in raw water showing peak constituent concentrations much lower than those of the other three MWTFs upstream. Furthermore, the dilution reduces the number of months during which constituent concentrations exceed the upper limits of what is normally experienced. Existing treatment operations, therefore, may be sufficient to bring hardness and TDS down to acceptable levels even during overflow periods. Sulfate and sodium levels will remain high, however, so that bottled water (or a suitable alternative) may have to be provided, particularly for at-risk members of the communities.

Table 3-1 Municipal Water Treatment Facility Raw Water Quality for Trace 2415

	Valley City	Fargo	Grand Forks	Grafton	Drayton	Pembina, Morris, Letelier
Total Hardness, mg/L (there is no secondary standard for total hardness)						
Peak Value	990	890	580	370	380	410
Normal Range*	200-340	180-400	220-340	200-290	200-300	200-310
Months of Exceedance**	47	35	19	10	10	9
Non-Carbonate Hardness, mg/L (there is no secondary standard for non-carbonate hardness)						
Peak Value	460	390	210	100	100	140
Normal Range	10-40	10-60	20-60	20-60	20-70	20-80
Months of Exceedance	53	52	22	14	12	8
Total Dissolved Solids, mg/L (the SDWA secondary standard for TDS is 500 mg/L)						
Peak Value	3850	3340	1810	870	880	880
Normal Range	330-630	320-700	330-490	310-420	310-440	320-460
Months of Exceedance	53	48	33	25	24	24
Sulfate, mg/L (the SDWA secondary standard for sulfate is 250 mg/L)						
Peak Value	1890	1620	810	340	340	340
Normal Range	90-180	90-200	70-120	50-100	60-110	50-120
Months of Exceedance	53	50	41	29	30	25
Chloride, mg/L (there is no secondary standard for chloride)						
Peak Value	390	330	170	70	70	70
Normal Range	10-20	10-20	10-30	10-20	10-30	10-30
Months of Exceedance	53	54	34	22	21	15
Sodium, mg/L (W.H.O. guideline = 200 mg/L; USEPA guidance level for an at-risk population = 20 mg/L)						
Peak Value	850	730	370	150	150	150
Normal Range	40-80	40-90	30-50	20-40	30-50	20-50
Months of Exceedance	53	50	41	29	30	25

* The normal range is defined as the mean value (calculated excluding the 2016-2023 overflow years) plus or minus two standard deviations.
** A month of exceedance is a month during the overflow years when the monthly mean value exceeds the high end of the normal range.

4.0 Industrial Users' Response to a Spill

The March 1999 study examined the potential impact of the Devils Lake emergency outlet on permitted industrial users that may be affected by changes in river water quality. After sorting out permittees holding multiple permits and permit holders reported by both North Dakota and Minnesota, 11 industries were identified that currently hold permits to draw water from the Sheyenne River or the Red River of the North along portions of the rivers that could potentially be affected by outlet pumping. These same 11 industrial users were evaluated for impacts in the event of a Stump Lake spill.

Holders of all 11 industrial permits were contacted and interviewed as part of the original study. The permitted users were interviewed to determine what processes at the facility use river water, the facility's water quality requirements, their treatment processes (if any), the water quantity requirements, and to discuss what the potential effects lower river water quality would have on their facility. Using the initial interview data, the industrial users were sorted according to which might potentially be affected by a decrease in river water quality. Those potentially affected were interviewed further to evaluate the likely effects of decreased river water quality.

4.1 Unaffected Industrial Users

The interviews conducted for the March 1999 study showed that eight of the eleven permit holders would not be impacted by the decrease in river water quality. Five of the eleven permit holders do not currently use river water, but continue to maintain their permits. Four of these permit holders have no plans to use river water in the future. The fifth (a construction company) may use river water to wash rocks in the future, but would not be affected by an increase in hardness or TDS. Two permittees currently use river water to wash sand and gravel, and so would not be affected by an overflow from Stump Lake. Another permit holder, the Fort Ransom Ski Resort, uses the river water to make snow. The Resort does not treat the water, and believes that increased hardness would not adversely affect its snow-making operations.

The following paragraphs describe each of the eight unaffected industries listed as unaffected in the March 1999 study. Potential effects of Trace 2415 data are noted.

Sheyenne Sand and Gravel is located in Sheyenne, North Dakota. Sheyenne Sand and Gravel currently uses the Sheyenne River to wash aggregate and gravel. They use approximately 65 millions gallons of untreated river water per year to wash sand and gravel. Although this industry would likely see the greatest deterioration in water quality due to its proximity to the overflow point, it was determined that a change in water quality due to an overflow as shown in Trace 2415 would not affect their operations.

Blumer Construction is located in Valley City, North Dakota. During interviews for the March 1999 study, the company indicated that it holds the permit in case it decides to use the river in the future. Company representatives stated that they might decide to use the river in 5 to 10 years to wash rock material. Based upon their planned uses of the water, a change in water quality due to an overflow from Stump lake would not likely affect the Company

Fort Ransom Ski Area (formerly Winter Sports Ltd.) is located in Fort Ransom North Dakota. Fort Ransom Ski Area currently uses the Sheyenne River to make snow. The rate of water usage varies depending on the amount of snowfall. From 1996 through 1998 they have averaged 2.3 million gallons per year. They do not treat the river water that they use and do not anticipate any problems due to a decrease in water quality. The TDS of the river water, though high by surface water standards, is not high enough to cause significant freezing point depression. Furthermore, Trace 2415 data shows most of the overflow from Stump Lake occurring during the spring and summer months; snow is only made in the winter. Potential impacts on the ski area grass have not been addressed, although there is some possibility that the melting river water could have an adverse effect on the turf (see discussion in Section 5.2.1).

Gutzmer Construction is located in Lisbon, North Dakota. Gutzmer Construction currently draws water from the Sheyenne River from April to November to wash aggregate rock. In 1997, the company used 6.3 million gallons of river water; it does not treat the water. Based on conversations with company personnel, the water quality indicated by the Trace 2415 data is not likely to have an adverse effect on the company's operations.

City of West Fargo, North Dakota. The City of West Fargo currently does not use any river water. The interviewee stated that it has been the city's policy to maintain all use permits in case the city were to have a problem with its groundwater source use for determining water supply. The city has no plans for drawing water from the river in the future, and is not likely to be affected adversely by an overflow from Stump Lake.

Building Products and Concrete Supply Ltd. is located in Winnipeg, Manitoba. This facility does not currently draw water from the Red River of the North. The operations manager did not know of the permit, but suggested that it may be for prior to 1979 when the plant was located near the river. In 1979, they moved to another location, approximately 5 miles from the Red River of the North. They do not currently use river water, nor do they have any plans to use river water.

Rogers Sugar Ltd. (formerly Manitoba Sugar Company), is located in Winnipeg, Manitoba. Although the company holds a permit to withdraw water from the Red River of the North, the Winnipeg plant has been closed and they have no plans to operate the facility in the future. At the time of the interviews, they were in the process of selling the equipment and had intentions of selling the property. No water is currently being drawn from the river at the site, and it is unlikely the company will use the river in the future.

City of Winnipeg, Manitoba. In the past, the City of Winnipeg operated a coal-fired generator station that used water from the Red River of the North. City of Winnipeg staff report that this station hasn't been used in a long time and that they have no plans to operate it in the future. They have no plans to use the river water.

4.2 Affected Industrial Users

The interviews conducted for the March 1999 study showed that three of the 11 industries having water permits were found to have potential for adverse impacts due to deterioration in the quality of the river water. The following paragraphs describe these industries and give a brief description of potential impacts and water use alternatives for each of the industries.

American Crystal Sugar is located in Drayton, North Dakota. American Crystal Sugar's Drayton facility is a sugar beet processing plant. There are several American Crystal Sugar plants in the area, but this is the only facility that uses water from the Red River of the North. The company currently holds two permits, and draws water from the Red River of the North.

The river water is used as cooling water and to supplement the process water when needed. American Crystal Sugar has traditionally used less than 110 million gallons per year (274,000GPD). Water is withdrawn from the river in the fall and stored for year-round use in an on-site storage basin. Data obtained from the North Dakota State Water Commission indicated that in the past they have traditionally taken water during the months of September, October, and November.

The company representative interviewed did not discuss treatment of the cooling water or the impact of high TDS and high hardness concentrations on the cooling process. However, based on experience with cooling water systems, it is likely that TDS and high hardness water would have a negative impact on that process. These waters would become even more concentrated through the cooling process as heat evaporates the water and concentrates the contaminants even further. Water high in hardness and TDS will cause precipitation to occur on the heat transfer surfaces.

Occasionally, river water is also used to supplement the process water at this facility. The company prefers to use beet water for this process if possible. When it is not possible, the company uses river water and treats it for hardness, filters it through diatomaceous earth and then boils it. The sugar beet processing facility declined to provide any other detailed information, stating that water usage is an integral part of their process and they did not want to reveal trade secrets. However, since some treatment of the water takes place, it can be assumed that an overflow from Stump Lake would also have a negative impact on this process.

The interviewee stated that a decrease in water quality would likely have a negative effect on the company's operations. If the water quality changes on a long-term basis, the company would likely need to find a new water source or make modifications in the factory set-up. Drayton is in an area of the state with virtually no usable groundwater, so wells are not an option. Rural water is available in the area, but would likely be much more expensive than using river water.

Because river water is not withdrawn continuously at the plant, however, one option to limit the impact of an overflow on this facility would be to limit their withdrawals of water to periods of good river water quality. Trace 2415 data for Drayton indicates that although the river water concentration of TDS and hardness show spikes over a period of several years, there are months during the overflow period when the river concentrations are not much greater than the average concentrations.

Manitoba Hydro is located in Winnipeg, Manitoba. Manitoba Hydro pumps water continuously from the river. Each pump has a capacity of 103 MGD. However, a company representative indicated that they have rarely pumped at the maximum capacity and do not anticipate that they would in the future. The interviewee indicated that the average flows were highly variable but declined to provide any flow rates.

Manitoba Hydro uses Red River of the North water for three different operations. The majority of the water (99 percent) is used as once-through cooling water for the condenser units. Less than 1 percent of the water is used to transport fly ash to an ash lagoon. The remaining water (less than 1 percent) is demineralized using ion exchange and used for boiler feed pump cooling and occasionally boiler make-up.

Trace 2415 data at Emerson was used to evaluate potential effects of an overflow on this facility. The TDS concentrations rise from an average of approximately 400 mg/L to a maximum of nearly 900 mg/L during an overflow from Stump Lake. Hardness also increases as a results of the overflow. Based on a review of solubilities, the solubilities of the TDS constituent compounds are much higher than the concentrations of Trace 2415 at Emerson. It is unlikely, therefore, that there would be a problem using this water for once-through cooling at the hydropower plant. Similarly, high TDS concentrations in the overflow water from Stump Lake would not adversely affect the fly ash transport process.

The river water used for boiler feed pump cooling and boiler make-up is treated for hardness to reduce scaling in the boilers. The elevated hardness in the Stump Lake overflow water would, therefore, be of concern to plant operators. Although flow rates for this use were not provided by the power plant, the rates were estimated based on the plant's pumping capacity and the percent of water treated. Using this approach, it is estimated that a maximum of 195,000 gallons per day (GPD) is used for cooling and boiler make-up. It is likely that the existing ion exchange unit could accommodate the high TDS and high hardness water indicated for Trace 2415. Treatment costs would be higher, however, due to increased O&M, brine disposal, and ion exchange regenerant costs.

Another option to lessen the impact of an overflow may be to use well water for pump cooling and boiler make-up water. The facility has an active well that is used for drinking water. Should the water quality in the Red River of the North degrade to the point where it could no longer be used for boiler feed pump cooling or boiler make-up water, well water could provide a substitute. The capacity and water quality for the well have not been evaluated for this analysis. However, using either the existing well or installing an additional well might provide a long-term solution. The well water could be used directly or blended with river water to provide water of acceptable quality.

Gateway Industries Ltd. is located in Winnipeg, Manitoba. Gateway Industries uses the water for from the Red River of the North for transport of paper fiber, paper processing, and washing of machinery. They draw approximately 50,000 gallons per day from the Red River of the North. The water is treated by filtering it with successively smaller filters to remove solids. The water chemist interviewed indicated there should be no effect on the chemical process of their current papermaking operations if the water quality were to change. However, the lower water quality would likely increase the load on their filters.

If the company were to expand operations to include the production of white paper, it would require high quality water. The interviewee was unable to state precisely what effect increased dissolved solids would have on the making of white paper. It is possible the company might expand to make white paper in the next 3 to 5 years, but the company's plans were tentative at the time of the interview.

Of all the industrial users, the Gateway Industries facility is the farthest downstream from the point of overflow and would experience the least impact from a Stump Lake overflow. The Trace 2415 data at Emerson was used to estimate overflow water quality at this paper manufacturing facility. Although the monthly average TDS concentration doubles at times during an overflow, it never reaches more than 900 mg/L (monthly average) for the trace. This information, coupled with that given by Gateway's chemist, indicates that the impact of an overflow on this facility is likely to be minimal.

4.3 Summary and Discussion

The eleven permitted industrial users of Sheyenne River and Red River of the North water include five permittees that do not currently use river water, and have no plans to do so in the foreseeable future. Because of the nature of their uses for the river water, three other permitted industrial users are unlikely to experience adverse effects from a Stump Lake Spill.

Three of the industrial users, however, may be affected adversely by overflows from Stump Lake. These users include a sugar beet processing facility, a power plant, and a paper mill. Each of these facilities currently treats river water to purify the water for its processing needs. Therefore, the water may be unusable, or may cause the facilities to experience higher treatment costs.

However, two of these users appear to have options by which they could mitigate or avoid the negative consequences of the deteriorated water quality. The sugar beet processing facility may be able to withdraw water during periods when Stump Lake is not overflowing, thereby avoiding use of high TDS water. The power plant may be able to use well water as a supplement or substitute for the relatively minor amounts of river water it requires for cooling and boiler water make-up.

The paper manufacturing facility, being farthest removed from the point of overflow, is likely to experience relatively minor deterioration in the quality of the river water it uses. Some higher treatment (filtering) costs may be experienced.

5.0 Spill Effects on Other Permitted Water Users

In addition to effects on MWTFs and industrial water users, a Stump Lake overflow will have effects on other permitted users along the Sheyenne River and Red River of the North. Most of these other permitted users use the river water for irrigation. Of principal concern are the impacts that high concentrations of total dissolved solids (TDS) would have on such users.

The potential effects of changing water quality on permitted users of river water were previously examined through contacts with local agencies and research on each type of use, as described in the March 1999 study. Based on the type of use, the extent of potential impacts can also be estimated for the Stump Lake overflow cases. As was the case with the municipal and industrial users, only one overflow condition (Trace 2415) was evaluated to estimate the level of impacts on permitted users.

5.1 Potential Effects on Other Permitted Users

5.1.1 Effects of High TDS Concentrations on Plants

For all plants, salinity (high TDS concentrations) in the root zone can reduce water uptake, restrict root growth, cause burning of the foliage, inhibit flowering, and limit fruit and vegetable yields. Such damages can be merely a nuisance, or can result in large-scale economic losses if crop yields are reduced.

As described in the March 1999 study, the tolerance of crops, trees, shrubs, gardens, and grasses to TDS is directly related to the type of soil in which they are grown. Soil type affects the movement of water through the soil, and less-permeable soils are considered to be less desirable when irrigation water is high in salinity. Other factors (irrigation amounts, timing of irrigation, climate, crop variety and growth stage, etc.) being equal, crops grown in such soils may be expected to be more susceptible to the potential adverse effects of saline water.

5.1.2 Threshold Levels for Plants and Animals

The March 1999 study described the research that was conducted to define estimated “threshold” water quality levels for various river water uses. For water used in irrigation, these thresholds are the TDS concentrations above which plant damage can be expected to occur. Exceedance of the thresholds during the Stump Lake overflow conditions can be similarly evaluated for each reach of the two rivers, with exceedance determinations based on Trace 2415.

The threshold levels (as developed in the March 1999 study) of the various agricultural crops and cultivated plants grown in the study area have been reprinted in Tables 5-1 and 5-2. Threshold levels can be seen to be based on the particular tolerance of the crop, and on the soil type in which it is grown. The center of the listed range was used as the threshold level.

The relative tolerance of other non-agricultural plant species were not studied in detail; Table 5-3 provides a partial listing of these plant species and their relative salt tolerance. According to this list, there are several trees and shrubs that are described as "non-tolerant" with plant damage expected at TDS concentrations of 0 to 1,400 mg/L. All other listed trees and shrubs are tolerant of salinity levels over 1,400 mg/L. The list also shows that all grasses are tolerant of salinity levels of over 1,400 mg/L.

Threshold levels for livestock were also discussed in the March 1999 study. The threshold level for TDS was estimated to be 1,000 mg/L for poultry and 3,000 mg/L for all other livestock (cattle, sheep, horses, etc.). The threshold level for sulfates was assumed to be 450 mg/L for all livestock (although there may be effects on the very young at lower sulfate concentrations).

Fish can also be affected by high TDS concentrations. River water is used throughout the year by fish hatcheries along the rivers to raise sport fish (northern, walleye, perch, and bluegill) and some non-game species including catfish, sturgeon, and bony-tailed chub. For TDS, a conservative estimate (based on very limited data) of 1,000 mg/L was used to assess potential impacts of the Stump Lake overflow. Data regarding fish tolerance to sulfate was unavailable, therefore threshold levels for sulfate (with respect to fish mortality) were not established.

5.1.3 Identification of Potentially Affected Users

The identification of affected users for the Stump Lake overflow case (Trace 2415) was conducted using the same methodology as the analysis completed for the March 1999 study. The analysis required a breakdown of the permit data by reach and specific type of use (type of crop grown, type of livestock raised, type of grass grown, etc.). The threshold levels and soil types were then used to identify which permitted users would be affected by the high TDS concentrations. Because water use permit information lists only the general type of use (irrigation, recreation, fish and wildlife, etc.), county-by-county agricultural use averages and user interview data were used to estimate the number of users according to specific type of use.

The maximum monthly averages of water quality constituents for each HEC-5/5Q trace data station were computed using only the May through September (growing season) data for determination of threshold level exceedances. This analysis for Trace 2415 was completed using a computer spreadsheet that computes the affected acreage for a particular trace based on a combination of these four factors (permit location, type of use, soil type, and threshold level) for the specified period of analysis.

As was done for the March 1999 study, non-agricultural irrigators were considered in aggregate, because listings of the specific types of non-agricultural plants grown by these non-agricultural irrigators were not available. No county data were available to allow quantification of non-agricultural (trees, shrubs, lawns, garden vegetables, etc.) plant production. Furthermore, it is likely that each permittee uses the river water to grow more than one non-agricultural species. The only way to identify the type of specific use or the affected area would be to contact each permittee; such an effort was beyond the scope of this study.

5.1.4 Mitigation Alternatives and Costs

Mitigation alternatives for permitted users that would be affected by high TDS concentrations were described in the March 1999 study. These alternatives included well installation, connection to rural water supply, installation of a well and supply system for multiple permitted users, withdrawal from local tributary streams, or reimbursement for crop damage. An analysis of these alternatives and approximate costs (where applicable) for each was discussed in the March 1999 study.

5.2 Trace 2415 and Effects on Other Permitted Users

The results summarized here are based on the techniques referred to above, using Trace 2415 data and the threshold levels calculated as described in the March 1999 study. Trace 2415 shows extremely high levels of TDS during the principal overflow period of about 4 years (2016-2020).

The results presented here consider the tolerance and potential effects only at the peak TDS concentration level. However, the duration and extent of the overflow effects are dependent not only on the peak TDS concentration, but also on irrigation amounts, timing of irrigation, climatic conditions, crop variety and growth stage, and the duration of the high concentrations. Estimation of the effects of high-TDS irrigation is based on studies that were conducted in high-evaporative environments using irrigation as the only water source (see the March 1999 study). In addition, the need for irrigation may be reduced during overflow periods; an overflow would be expected during periods when rainfall is plentiful. Therefore, the results presented below may overstate the actual effects on individual users; careful management of the irrigation may considerably mitigate for high TDS concentrations.

5.2.1 Effects on Crops and Other Plants

Agricultural Crops

Table 5-4 lists the reaches in which the threshold levels for agricultural crops would be exceeded during the Stump Lake overflow condition. Comparison of trace data with threshold levels indicates that oats and sunflowers are the only crops that would not be affected by the TDS levels during Stump Lake overflow. The most widely affected crops are corn, dry edible beans, flax, and potatoes, which are affected under all soil types. For clayey soils, threshold tolerance is less, so that all agricultural areas, from the overflow to Lake Winnipeg, may be affected. However, regional data indicates that barley, corn and wheat are the only crops that are irrigated in this region, therefore the potential effects are limited to these agricultural crops.

Based on the crops planted, soil types, threshold levels, and location of the permitted users, the total acreage that would potentially be affected by the overflow salinity concentrations would be approximately 1,136 acres of barley, 49,177 acres of corn, and 3,278 acres of wheat. These potentially affected agricultural crop acreages are listed by river reach in Table 5-5.

Non-Agricultural Cultivated Plants

The high TDS levels during the Stump Lake overflow could affect virtually all of the irrigated non-agricultural plants grown along the Sheyenne River (for all soil types). About 80 percent of these cultivated plants would be affected from the overflow to Grand Forks for soil type A and from the overflow to Lake Winnipeg for soil type D: beans, cabbage, carrots, lettuce, onions, peppers, radishes, spinach, sweet corn, sweet potatoes, apples, pears, grapes, strawberries, plums, blackberries, raspberries, and boysenberries will potentially be adversely affected by irrigation using river water during the overflow. Table 5-6 lists the reaches where the potential effects would be seen (based on Trace 2415 overflow peak concentrations).

Based on the relative salt tolerance levels listed in Table 5-3 and the Trace 2415 concentrations, only moderately tolerant and tolerant cultivated plants could be grown along the Sheyenne River during the overflow condition (TDS levels exceed 2,800 mg/L). Along the Red River of the North, from the Junction to Grand Forks, the slightly tolerant cultivated plants (TDS levels >1,400 mg/L) might also survive. Downstream of Grand Forks, all cultivated plants would remain unaffected despite the overflow.

Based on Trace 2415 overflow data and the threshold TDS levels for grasses, the overflow water would not be suitable for irrigation of lawns or golf courses from the overflow point to Grand Forks (TDS levels >1,400 mg/L).

5.2.2 Effects on Poultry, Livestock, and Fish

Poultry

The assumed TDS threshold level of 1,000 mg/L for poultry is exceeded during many months of the primary overflow period, from the overflow point on the Sheyenne River and along the Red River of the North to Grand Forks. The effects of this exceedance on poultry are expected to include mild and temporary diarrhea, which would likely be more deleterious for young birds. However, the quantity of poultry raised by permittees that use river water is unknown. County agricultural data does not list poultry among the regional products, so it may be assumed that there are relatively few permittees that use river water to raise poultry. This assumption could only be verified by contacting each permittee; such contacts were not made for this analysis.

Livestock

The assumed TDS threshold level of 3,000 mg/L for livestock is exceeded during the overflow period from the overflow point on the Sheyenne River to the confluence of the Sheyenne River with the Red River of the North. The effect of the exceedance on the animals is expected to be mild and temporary diarrhea. These effects would likely be more harmful for young animals.

The assumed sulfate threshold level of 450 mg/L for all livestock is exceeded with the Stump Lake overflow from Cooperstown to Grand Forks. The adverse effects from sulfate levels between 350 mg/L and 450 mg/L would include diarrhea, electrolyte imbalance, and sometimes death in young animals. Milk fat percentages may also be lower in dairy cattle when consuming water above

600 mg/L sulfate. As with poultry, the exact number of livestock producers cannot be obtained without contacting each permittee.

Fish

The U.S. Fish and Wildlife Service is listed as having ten permits, although this study identified only two fish hatcheries (Bald Hill and Valley City hatcheries, both located in Barnes County, North Dakota). The Trace 2415 data indicates a maximum monthly average TDS concentration of about 4,000 mg/L in this reach. This TDS concentration is significantly higher than the threshold level for fish of 1,000 mg/L. The ill effects of the high TDS levels would likely include poor egg hatching and limited survival of young fish. The extent of the actual damages incurred would be dependent on the type of fish raised, the age of the fish, any treatment of the water, and the timing of river water use. An alternative water source or treatment would likely be required for these hatcheries during the overflow period.

5.3 Mitigation Alternatives and Costs

As identified in the March 1999 study, the mitigation options for the non-MWTF, non-industrial permitted users consist of the following:

- Well installation
- Rural water supply connection
- Well installation and supply for multiple users
- Withdrawal from tributary stream
- Reimbursement for damages

Cost estimates were not made for providing compensation for reduced yields, or for the costs of providing alternative water supplies. Such costs would be difficult to assess and would have to be developed on a case-by-case basis.

5.4 Discussion and Summary

Comparison of the Trace 2415 data with threshold levels for salinity tolerance indicates that many non-MWTF, non-industrial users are likely to be affected by changes in water quality during a Stump

Lake overflow. Although the threshold values are likely to be extremely conservative, the ill effects on plants and animals would still be likely to occur with the high concentrations in the overflow.

However, it should be noted that Trace 2415 exceedances occur over a relatively short period of time (3 to 4 years), and only intermittently during the spring and summer months. Furthermore, the Trace 2415 data used for evaluating the effects on non-MWTF is only illustrative; actual water conditions will vary. Water quality during overflows from Stump Lake could be better or worse than the Trace 2415 data indicates, and the overflows could last for a longer or shorter period of time.

5.4.1 Effects of Trace 2415 Overflows

The effects of a Stump Lake overflow on non-MWTF, non-industrial permitted river water users will vary according to the use—irrigation, poultry, livestock, etc.—of the river water.

- Many non-agricultural cultivated plants are highly sensitive to salinity, and would be affected if irrigated with the Stump Lake overflow water during the high concentration period. There is very little data available on the amount of these non-agricultural cultivated plants grown and, therefore, no estimates of potentially affected acres can be computed. However, garden and nursery plants, landscape plants, and lawn and golf course grasses would likely be affected during the overflow period.

- High TDS and sulfate levels would affect livestock and poultry watered with river water during a Stump Lake overflow from the overflow point on the Sheyenne River to Grand Forks. The lack of available data on livestock and poultry numbers raised along these reaches makes it impossible to estimate the number of livestock potentially affected by the overflow. In general, however, the effects would likely be diarrhea, electrolyte imbalance, and sometimes death of the animals.

- Fish hatcheries in Barnes County would by affected by high TDS concentrations above the threshold level during a Stump Lake overflow. The effects would likely include poor egg hatching and limited survival of young fish. However, the extent of potential damages would be dependent on the type of fish raised, the age of the fish, the treatment of water, and the timing of river water use.

- Only for agricultural crops was the data sufficient to provide some quantification of the likely effects of an overflow. Irrigated agricultural crops potentially affected by the overflow TDS concentrations include barley, corn, and wheat, depending on the soil type in which the crop is grown. The potentially affected agricultural crop acreage is listed in Table 5-5. A total of about 1,136 acres of barley (98 percent), 49,177 acres of corn (85 percent), and 3,278 acres of wheat (9 percent) irrigated with the Stump Lake overflow water were estimated (according to methods described in the March 1999 study) to be potentially affected during the high concentration period.

5.4.2 Summary

Most of the permitted non-MWTF, non-industrial water users along the Sheyenne River and the Red River of the North use the river water for irrigation purposes. The irrigation water is used primarily for agricultural crops, but also for livestock, poultry, and non-agricultural cultivated plants in parks, cemeteries, nurseries, gardens, etc.). Because the water is used mostly for plants, most of the users withdraw water from the river during the growing season. The quantity of water withdrawn from the rivers varies from year to year for each of the irrigators, because the quantity differs depending on what is being watered, and the seasonal rainfall amount.

It is difficult to quantify the number of permitted users that will be adversely affected by a Stump Lake overflow. However, it appears that the effects will be most severe for those using the water for livestock and poultry, and irrigators of barley, corn, and wheat. County records indicate that the other non-tolerant agricultural crops (as listed in Table 5-4) are not prevalent along the affected river reaches. Garden and landscape plants, and grasses for golf courses and lawns, would also be adversely affected by the high TDS concentrations in a Stump Lake overflow.

Table 5-1
TDS Threshold Levels for Agricultural Crops

CROPS	TDS Threshold Level (mg/L) Soil Type A	Soil Type B	Soil Type C	Soil Type D
Barley	6753 - 7429	4906 - 6753	3852 - 4906	2889 - 3852
Corn	1435 - 1579	1042 - 1435	818 - 1042	614 - 818
Dry Edible Beans	844 - 929	613 - 844	481 - 613	360 - 481
Flax	1435 - 1579	1042 - 1435	818 - 1042	614 - 818
Hay*	4474 - 4921	3250 - 4474	2552 - 3250	1914 - 2552
Oats	N/A	N/A	N/A	N/A
Potato	1435 - 1579	1042 - 1435	818 - 1042	614 - 818
Rye	4726 - 5200	3434 - 4726	2696 - 3434	2022 - 2696
Soybean	4220 - 4643	3065 - 4220	2407 - 3065	1805 - 2407
Sugarbeet	5909 - 6500	4292 - 5909	3370 - 4292	2528 - 3370
Sunflower	N/A	N/A	N/A	N/A
Wheat	5064 - 5571	3679 - 5064	2889 - 3679	2166 - 2889

* Barley Hay

Notes: N/A denotes information not available for that crop.

Soil types are based on SCS hydrologic soil types as follows:

Type A Low runoff potential: high infiltration rates.
Type B Moderate infiltration rates.
Type C Slow infiltration rates.
Type D High runoff potential: slow infiltration rates.

Table 5-2
TDS Threshold Levels for Cultivated Plants

PLANTS	TDS Threshold Level (mg/L) Soil Type A	Soil Type B	Soil Type C	Soil Type D
Beans	844 - 929	613 - 844	482 - 613	361 - 482
Beets	3376 - 3714	2452 - 3376	1926 - 2452	1445 - 1926
Broccoli	2363 - 2600	1717 - 2363	1348 - 1717	1011 - 1348
Cabbage	1519 - 1671	1104 - 1519	866 - 1104	650 - 866
Cantaloupe	1857 - 2043	1349 - 1857	1060 - 1349	795 - 1060
Carrot	844 - 929	613 - 844	482 - 613	361 - 482
Cucumber	2111 - 2321	1533 - 2111	1203 - 1533	903 - 1203
Lettuce	1098 - 1207	797 - 1098	626 - 797	470 - 626
Onion	1013 - 1114	735 - 1013	578 - 735	434 - 578
Pepper	1266 - 1393	920 - 1266	722 - 920	541 - 722
Radish	1013 - 1114	735 - 1013	578 - 735	434 - 578
Spinach	1688 - 1857	1227 - 1688	963 - 1227	722 - 963
Sweet Corn	1435 - 1579	1043 - 1435	818 - 1043	614 - 818
Sweet Potato	1266 - 1393	920 - 1266	722 - 920	541 - 722
Tomato	2111 - 2321	1533 - 2111	1203 - 1533	903 - 1203
Apple, pear	1435 - 1579	1043 - 1435	818 - 1043	614 - 818
Grape	1519 - 1671	1104 - 1519	866 - 1104	650 - 866
Strawberry	844 - 929	613 - 844	482 - 613	361 - 482
Plum	1266 - 1393	920 - 1266	722 - 920	541 - 722
Blackberry	1266 - 1393	920 - 1266	722 - 920	541 - 722
Boysenberry	1266 - 1393	920 - 1266	722 - 920	541 - 722
Raspberry	844 - 929	613 - 844	482 - 613	361 - 482

Soil types are based on SCS hydrologic soil types as follows:

Type A Low runoff potential: high infiltration rates.
Type B Moderate infiltration rates.
Type C Slow infiltration rates.
Type D High runoff potential: slow infiltration rates.

Table 5-3 Relative Salt Tolerance of Various Cultivated Plants

Non Tolerant (0-1,400 mg/L)	Slightly Tolerant (1,400-2,800 mg/L)	Moderately Tolerant (2,400-5,600 mg/L)	Tolerant (5,600-11,200 mg/L)
Nurseries			
azalea cottoneaster red pine rose sugar maple viburnum white pine	apple forsythia linden Norway maple red maple	black locust boxwood beet red oak white ash white oak	arborvitae juniper Russian olive
Truck Gardening			
begonia blueberry carrot green bean onion pea radish raspberry strawberry	cabbage celery cucumber grape lettuce pepper potato snapdragon sweet corn	broccoli chrysanthemum geranium marigold muskmelon spinach squash tomato zinnia	asparagus Swiss chard
Golf Courses			
	creeping bentgrass Kentucky bluegrass perennial ryegrass red fescue	nugget Kentucky bluegrass seaside creeping bentgrass	alkaline grass

Source: Soil Test Interpretations and Fertilizer Management for Lawns, Turf Gardens, and Landscape Plants

Table 5-4 Reaches that Exceed the TDS Threshold Levels for Agricultural Crops Trace 2415 with Stump Lake Overflow (referenced between trace data stations)

Trace # 2415	**With Overflow**			
CROPS	**Soil Type A**	**Soil Type B**	**Soil Type C**	**Soil Type D**
Barley	NE	NE	NE	Outlet to Kindred
Corn	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Emerson
Dry Edible Beans	Outlet to Grand Forks	Outlet to Emerson	Outlet to Emerson	Outlet to Emerson
Flax	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Emerson
Hay *	NE	Outlet to Valley City	Outlet to Junction	Outlet to Junction
Oats	NE	NE	NE	NE
Potato	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Emerson
Rye	NE	NE	Outlet to Junction	Outlet to Junction
Soybean	NE	Outlet to Lisbon	Outlet to Junction	Outlet to Junction
Sugarbeet	NE	NE	Outlet to Valley City	Outlet to Junction
Sunflower	NE	NE	NE	NE
Wheat	NE	NE	Outlet to Kindred	Outlet to Junction

Notes: This table is based on trace 2415 and the average threshold levels by soil type.

Exceedance of threshold levels between Emerson and Lake Winnipeg was not evaluated.

* Barley Hay

NE indicates "No Effect"

Table 5-5 Potentially Affected Agricultural Crop Acreage Trace 2415 with Stump Lake Overflow

River Reach	Potentially Affected Agricultural Crop	Total Acres of Crops Grown	Acres of Potentially Affected Crops Based on Threshold Level and Soil types with Overflow
RED RIVER OF THE NORTH			
Lake Winnipeg to Emerson	Barley	N/A	0
	Corn	N/A	0
	Wheat	N/A	0
Emerson to Drayton	Barley	0	0
	Corn	1,914	657
	Wheat	2,392	0
Drayton to Oslo	Barley	0	0
	Corn	3,349	1,033
	Wheat	5,504	0
Oslo to Grand Forks	Barley	0	0
	Corn	5,161	1,676
	Wheat	7,723	0
Grand Forks to Halstad	Barley	0	0
	Corn	7,451	7,451
	Wheat	16,849	0
Subtotal	Barley	0	0
Red River of the North	Corn	17,874	10,818
	Wheat	32,468	0
SHEYENNE RIVER			
Junction to Kindred	Barley	141	141
	Corn	10,329	10,329
	Wheat	849	205
Kindred to Lisbon	Barley	0	0
	Corn	12,463	10,665
	Wheat	538	39
Lisbon to Valley City	Barley	0	0
	Corn	9,334	9,334
	Wheat	1,149	968
Valley City to Cooperstown	Barley	1,019	995
	Corn	5,097	4.973
	Wheat	1,019	785
Cooperstown to Natural Channel from Devils Lake	Barley	0	0
	Corn	3,058	3,058
	Wheat	2,112	1,280
Subtotal	Barley	1,161	1,136
Sheyenne River	Corn	40,281	38,359
	Wheat	5,668	3,278
TOTAL All Reaches	Barley	1,161	1,136
	Corn	58,156	49,177
	Wheat	38,136	3,278

N/A – Location of permitted users in Manitoba was not available, and is not included in this table

Table 5-6 Reaches that Exceed the TDS Threshold Levels for Cultivated Plants Trace 2415 with Stump Lake Overflow (referenced between trace data stations)

Trace # 2415	With Overflow			
PLANTS	**Soil Type A**	**Soil Type B**	**Soil Type C**	**Soil Type D**
Beans	Outlet to Grand Forks	Outlet to Emerson	Outlet to Emerson	Outlet to Emerson
Beets	Outlet to Kindred	Outlet to Junction	Outlet to Junction	Outlet to Halstad
Broccoli	Outlet to Junction	Outlet to Junction	Outlet to Grand Forks	Outlet to Grand Forks
Cabbage	Outlet to Halstad	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Emerson
Cantaloupe	Outlet to Junction	Outlet to Halstad	Outlet to Grand Forks	Outlet to Grand Forks
Carrot	Outlet to Grand Forks	Outlet to Emerson	Outlet to Emerson	Outlet to Emerson
Cucumber	Outlet to Junction	Outlet to Junction	Outlet to Grand Forks	Outlet to Grand Forks
Lettuce	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Emerson	Outlet to Emerson
Onion	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Emerson	Outlet to Emerson
Pepper	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Emerson	Outlet to Emerson
Radish	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Emerson	Outlet to Emerson
Spinach	Outlet to Halstad	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Emerson
Sweet Corn	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Emerson
Sweet Potato	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Emerson	Outlet to Emerson
Tomato	Outlet to Junction	Outlet to Junction	Outlet to Grand Forks	Outlet to Grand Forks
Apple, pear	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Emerson
Grape	Outlet to Halstad	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Emerson
Strawberry	Outlet to Grand Forks	Outlet to Emerson	Outlet to Emerson	Outlet to Emerson
Plum	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Emerson	Outlet to Emerson
Blackberry	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Emerson	Outlet to Emerson
Boysenberry	Outlet to Grand Forks	Outlet to Grand Forks	Outlet to Emerson	Outlet to Emerson
Raspberry	Outlet to Grand Forks	Outlet to Emerson	Outlet to Emerson	Outlet to Emerson

Notes: This table is based on trace 2415 and the average threshold levels by soil type.

Exceedance of threshold levels between Emerson and Lake Winnipeg was not evaluated.

6.0 Effects of a Spill on Non-Permitted Water Users

The potential effects of a Stump Lake overflow on the non-permitted river water users were not directly analyzed for this study, because little data is available regarding the types and frequency of use for this group. However, as was indicated in the March 1999 study, most of the non-permitted users are likely to be using river water for small-scale irrigation of landscape plants, lawns, and gardens. The effects of high-TDS water on landscape plants, grasses, and garden vegetables were discussed in Section 5 of this addendum. However, several additional types of non-permitted uses were identified in the March 1999 study, and the effects for these uses are addressed below

Assessment of the potential effects of a Stump Lake overflow on non-permitted users is based on information garnered through interviews of a representative sample of the non-permitted users. These interviews were conducted for the original March 1999 study.

6.1 Identification of Threshold Levels

The types of non-permitted river water uses identified in the March 1999 study are listed in Table 6-1. Threshold levels for most of these uses were determined and defined in Section 5.1.2 for other permitted (non-MWTF, non-industrial) users. The main difference between the permitted and non-permitted users is the amount of annual water use; non-permitted users are expected to use a relatively small amount of river water.

"Threshold levels" for domestic drinking water use for non-permitted users can be considered to be the secondary drinking water standards previously identified in Section 3.1 of this addendum.

6.2 Effects on Non-Permitted Users

The potential effects of high water quality constituent concentrations resulting from a Stump Lake overflow are generally similar to those summarized for the non-MWTF, non-industrial permitted users in Section 5. Most of the non-permitted users use river water for small-scale irrigation of lawns, gardens, and shrubbery.

Some non-permitted users use the river water for domestic drinking water. The March 1999 study identified two non-permitted water user respondents who use the water as their primary drinking water source through the entire year.

One non-permitted user also withdraws water from Lake Ashtabula to fill a camp swimming pool, a use which could result in slight human ingestion of the river. The Stump Lake overflow concentrations exceed the US EPA secondary drinking water standards for sulfate (250 mg/L) and TDS (500 mg/L). Water exceeding these standards may have taste and odor problems, and consumption of water exceeding these levels may result in laxative effects.

6.3 Summary and Discussion

The impacts that the Stump Lake overflow water would have on non-permitted users varies according to the type of use and the degree of reliance on the river water (quantity of use). However, it is not possible to quantify the number of non-permitted users that will be adversely affected by the Stump Lake overflow with the available data.

Most of the non-permitted interviewees are withdrawing water for lawn, garden, and livestock watering. The high-TDS water that would be generated during a Stump Lake overflow potentially affects all of these uses. Domestic drinking water users will also be adversely affected during an overflow period.

Table 6-1 Types of Non-Permitted Water Use

Type of Use	Description of Use	Seasonal Timing of Use
Domestic	Water used as primary drinking water source and for all household activities.	Spring, Summer, Fall, and Winter
Livestock	Watering cattle and/or sheep by pumping water from the river or by having pasture lands adjacent to the river's edge.	Spring, Summer, Fall, and Winter
Domestic Garden	Irrigation of domestic flowers and vegetables: tomatoes, peas, beans, sweet corn, etc.	Summer
Lawns	Irrigation of private lawns and shrubbery.	Spring and Summer
Trees and Shrubs	Irrigation of trees and shrubs: domestic and commercial.	Spring, Summer, and Fall
Recreation	Water used to fill camp swimming pool.	Summer
Commercial Gardeners	Irrigation of commercial fruit and vegetable crops, such as tomatoes, peppers, cucumbers, onions, strawberries, etc.	Spring and Summer

7.0 Summary and Conclusions

Examination of Trace 2415 (developed in April 1999) provides a means by which to examine the potential consequences of an overflow from Stump Lake. It must be kept in mind that the Trace 2415 data is only an example of what sort of flows and water quality might be expected in the event of an overflow. Should an overflow actually take place, the flow rate, flow duration, and resultant constituent concentrations in the Sheyenne River and the Red River of the North will be different from those indicated by Trace 2415.

Nevertheless, examination of the 50 years of Trace 2415 data provides an idea of what water quality changes may occur, and the sorts of flow patterns that may occur. Trace 2415 data shows a primary overflow period in the years 2016 through 2023, with minor spills from Stump Lake occurring in later years. For the water quality constituents modeled, the concentration changes are extreme during the overflow period, particularly in the farthest upstream reaches of the Sheyenne River. The dilution provided by the Red River of the North and its tributaries reduces the peak concentrations as the overflow plume moves downstream. As a result, adverse effects on water users can be expected to be less severe as one continues downstream.

An overflow from Stump Lake will cause peaks in the concentrations of dissolved solids in the river water. The elevated concentrations will certainly have consequences for downstream users of river water. These impacts will depend on what the river water is used for, the timing and seasonality of the use, the amount of withdrawal, and (as was mentioned) the distance downstream from the point at which the overflow water enters the Sheyenne River.

Municipal Water Treatment Facilities - For the MWTFs, the impacts will vary according to the location of the water treatment facility, and the ability of the facility to readily switch to an alternative raw water source. The MWTF at Valley City will be most strongly affected, with the MWTFs at Fargo and Grand Forks also experiencing difficulties in providing safe and aesthetically acceptable drinking water during overflow periods. The existing river water withdrawal and water treatment regimes at these MWTFs will be insufficient to provide acceptable drinking water for the communities. Alternative raw water sources, ion exchange treatment, and/or provision of bottled water will be necessary.

The MWTFs farther downstream – those at Grafton, Drayton, Pembina, Morris, and Letelier – will experience relatively less severe problems, and for shorter durations, when an overflow occurs. Existing treatment methods may be sufficient for bringing the treated water within acceptable limits during some of the overflow periods. Provision of bottled water is also likely to be required at times, at least for at-risk individuals.

Industrial Users – Only three of the eleven permitted industrial users are likely to experience adverse effects as a result of a Stump Lake overflow. For one of those potentially affected industrial users (the paper mill, located farthest from the Sheyenne River), the effects of the overflow may be relatively minor and inconsequential. For the power plant and the sugar beet processing facility, it may be possible to use selective withdrawals, increased treatment, or alternative water sources to mitigate the adverse effects of the overflow.

Other Permitted Users – Most of the non-MWTF, non-industrial permitted users of river water use the water for irrigation of crops and garden plants, or for watering livestock. The high TDS and sulfate levels resulting from an overflow from Stump Lake have the potential for harming both plants and animals. Of all of the crop acreage currently irrigated with river water, 98 percent of the irrigated barley acreage, 85 percent of the irrigated corn acreage, and 9 percent of the irrigated wheat acreage will potentially be affected by the high TDS concentrations. Fish hatcheries will also be potentially affected by the high TDS concentrations in the river water. The degree of the adverse effects will depend on the soil type, the particular plant or animal species for which the water is used, and the timing and amount of the river water withdrawal.

Non-Permitted Users – The ill effects of a Stump Lake overflow on non-permitted river water users will be similar to those experienced by the non-MWTF, non-industrial permitted users. Although data is scarce with respect to this group, most of the non-permitted users appear to use river water for small-scale irrigation of lawns and gardens. As with the permitted users, the effects on non-permitted users will depend on the type of plant for which the water is used, and the timing and amount of the river water withdrawal.